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**McCune**

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(54) **TURBINE ENGINE GEARBOX**

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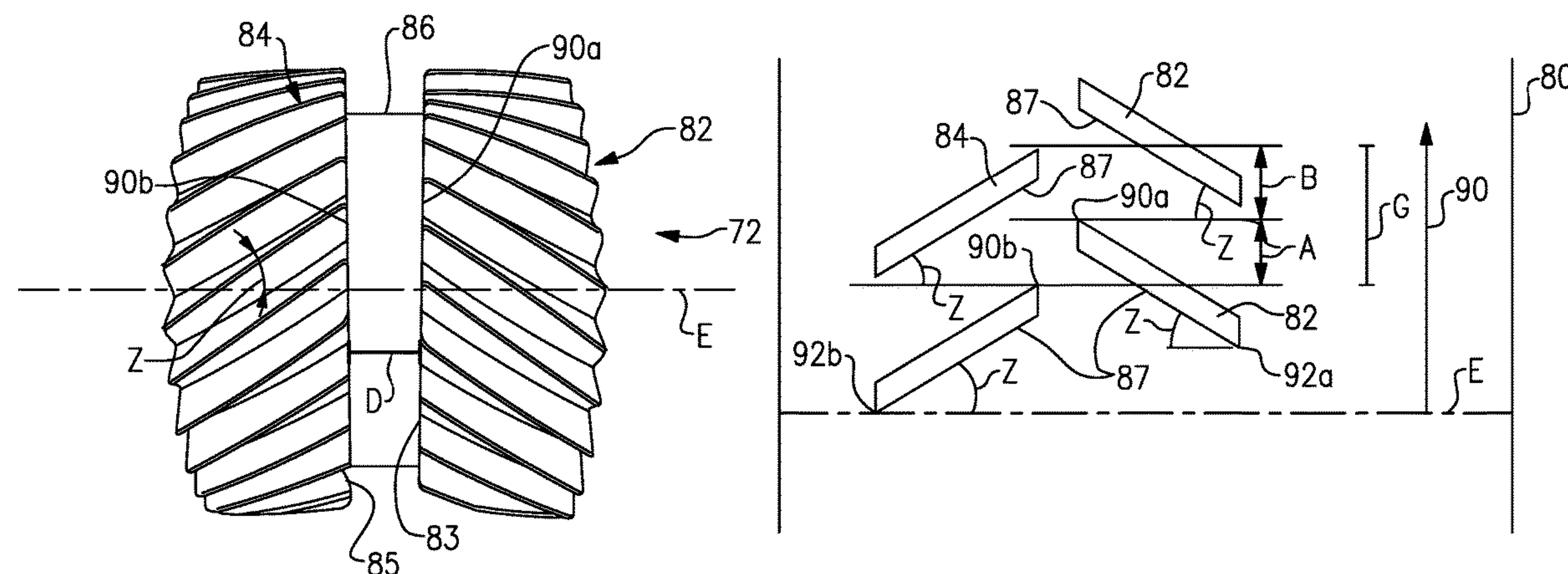
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(57) **ABSTRACT**

A gas turbine engine according to an example of the present disclosure includes, among other things, a fan section, a compressor section, and a turbine section including a fan drive turbine that drives the fan through a gear reduction. The gear reduction includes at least two double helical gears in meshed engagement, each of the at least two double helical gears having a first plurality of gear teeth separated from a second plurality of gear teeth such that a first end of the first plurality of gear teeth and a first end of the second plurality of gear teeth are spaced apart by an axial distance. Each of the first plurality of gear teeth is offset a first circumferential offset distance in relation to the next gear tooth of the second plurality of gear teeth when moving in a circumferential direction relative to respective axes.

**27 Claims, 5 Drawing Sheets**



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See application file for complete search history.

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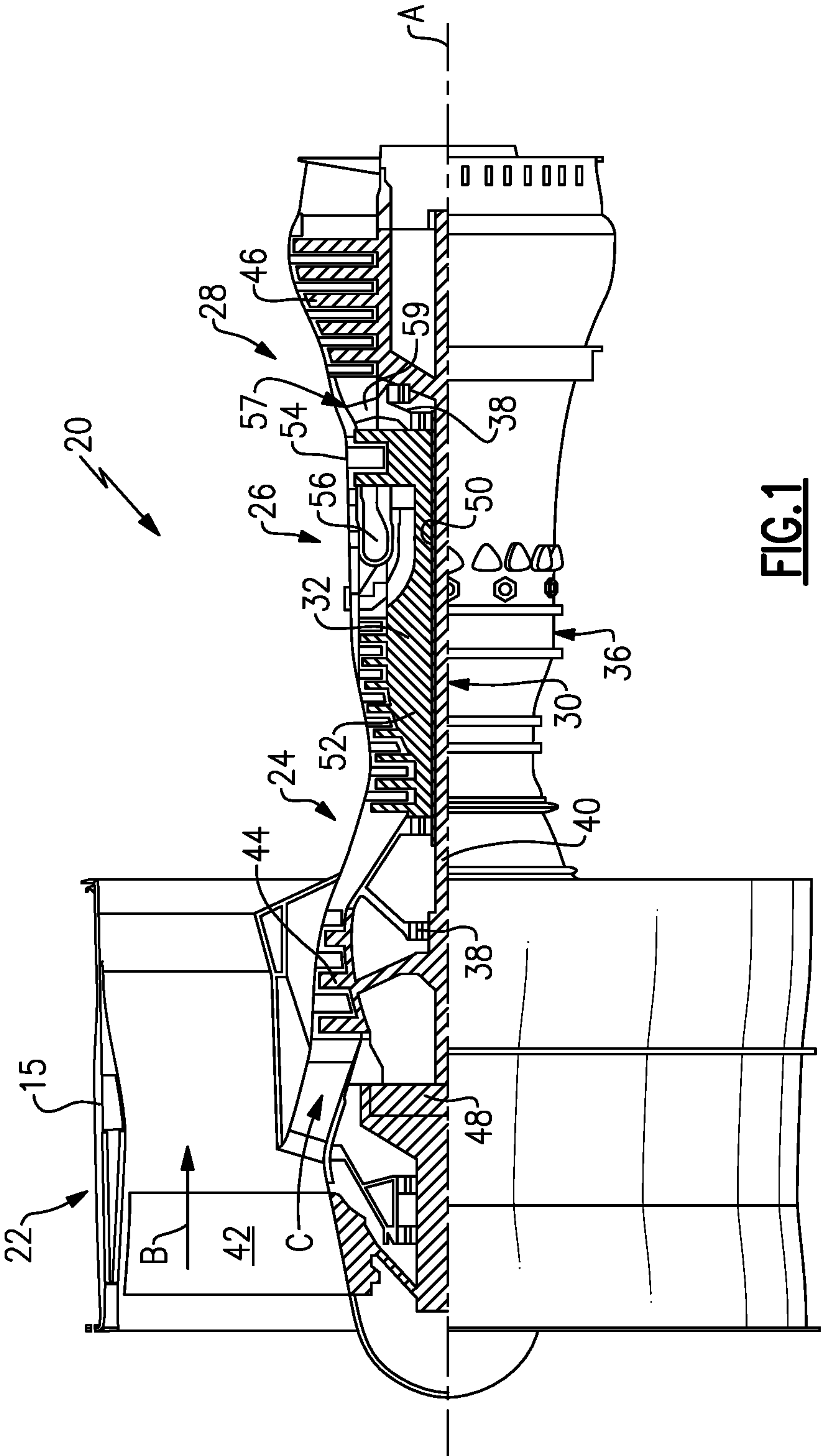
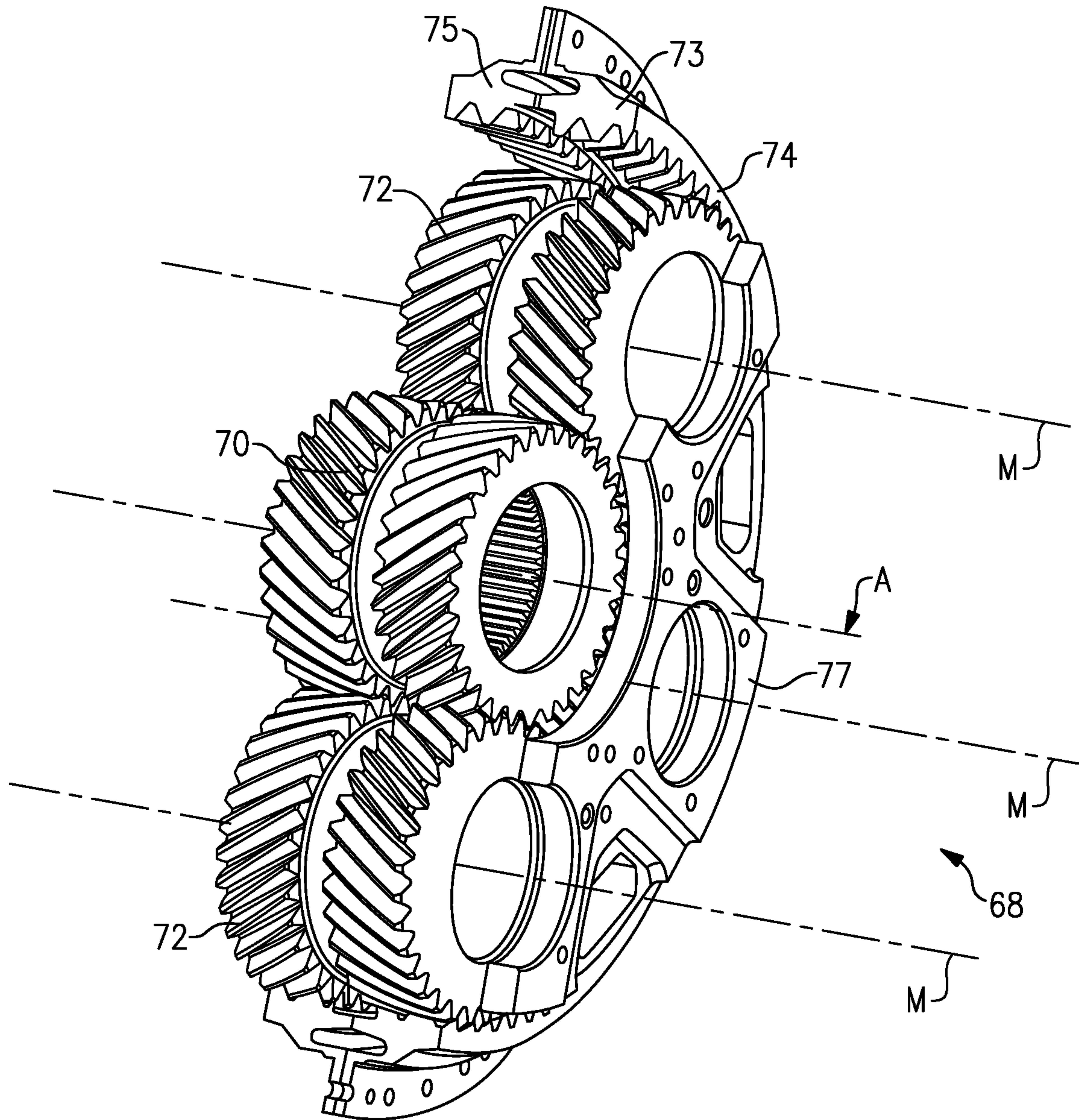


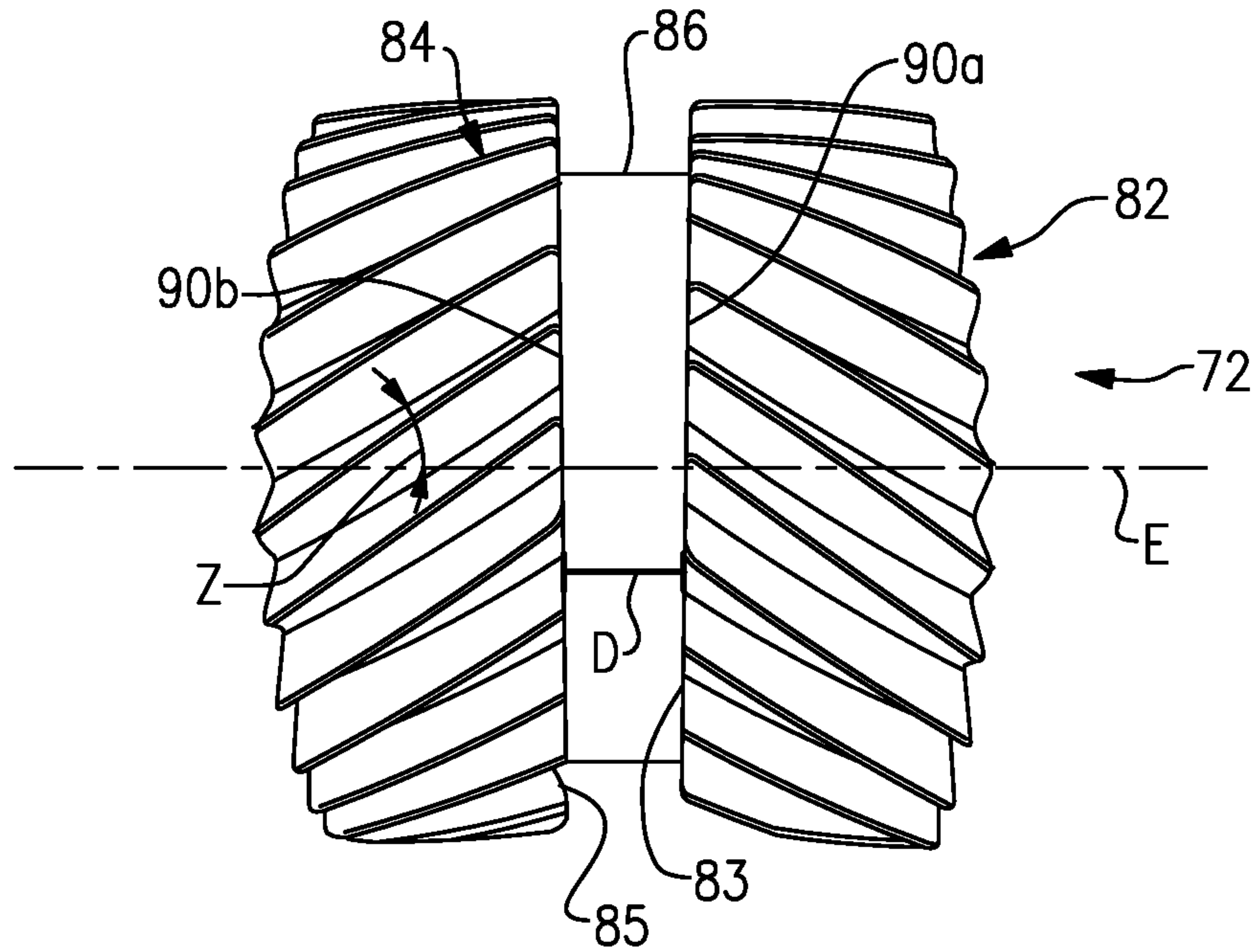
FIG. 1



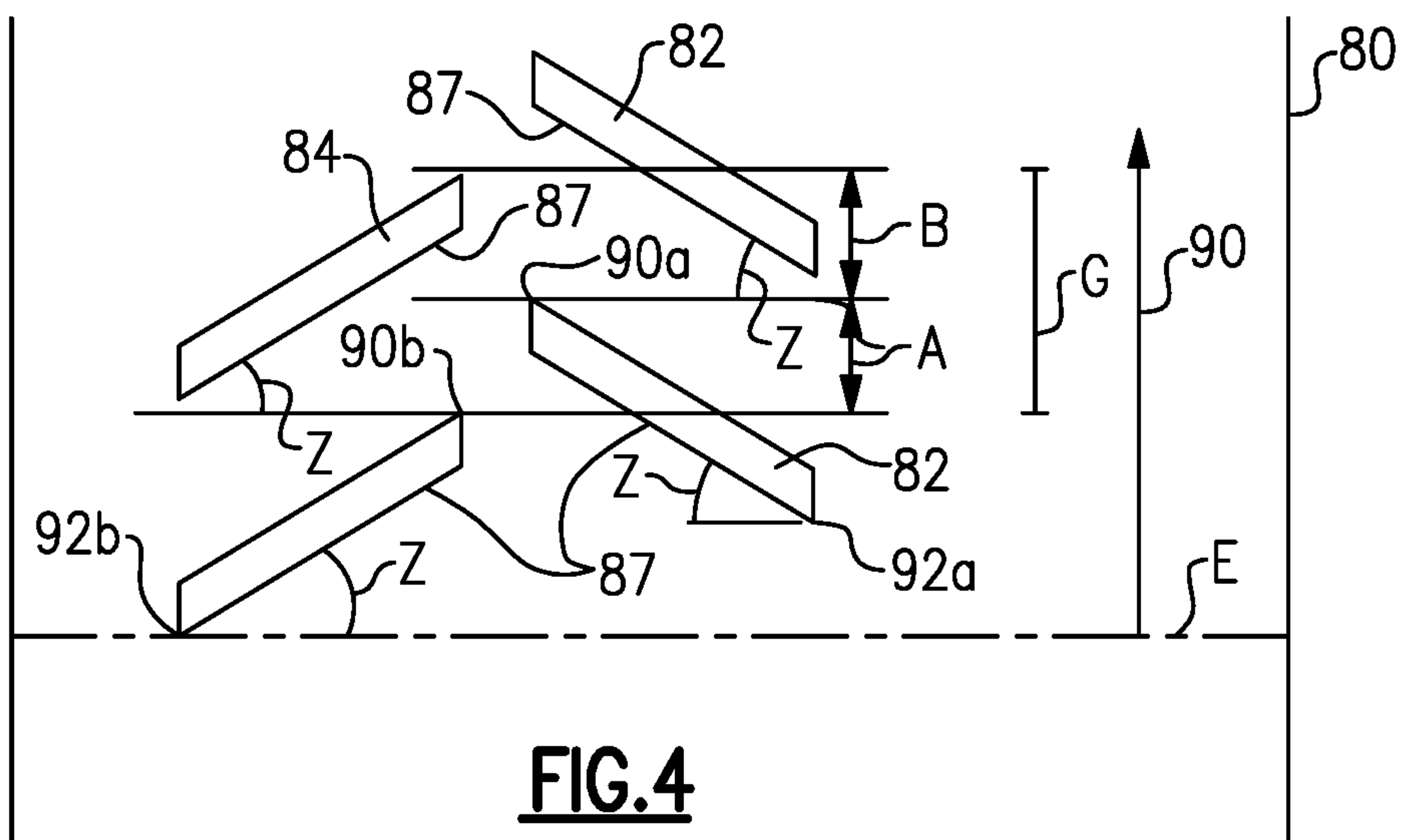


**FIG. 2**





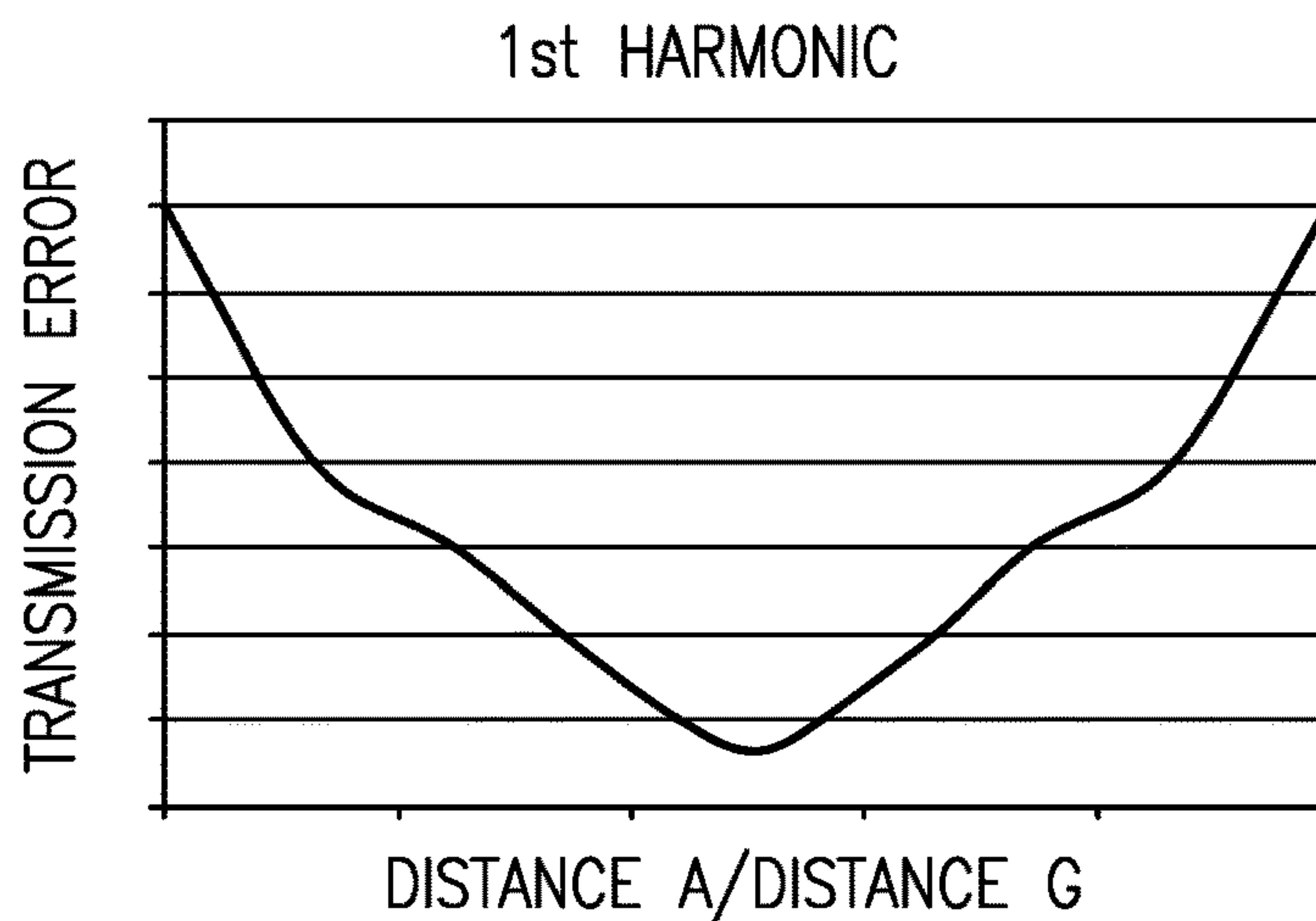
**FIG. 3**



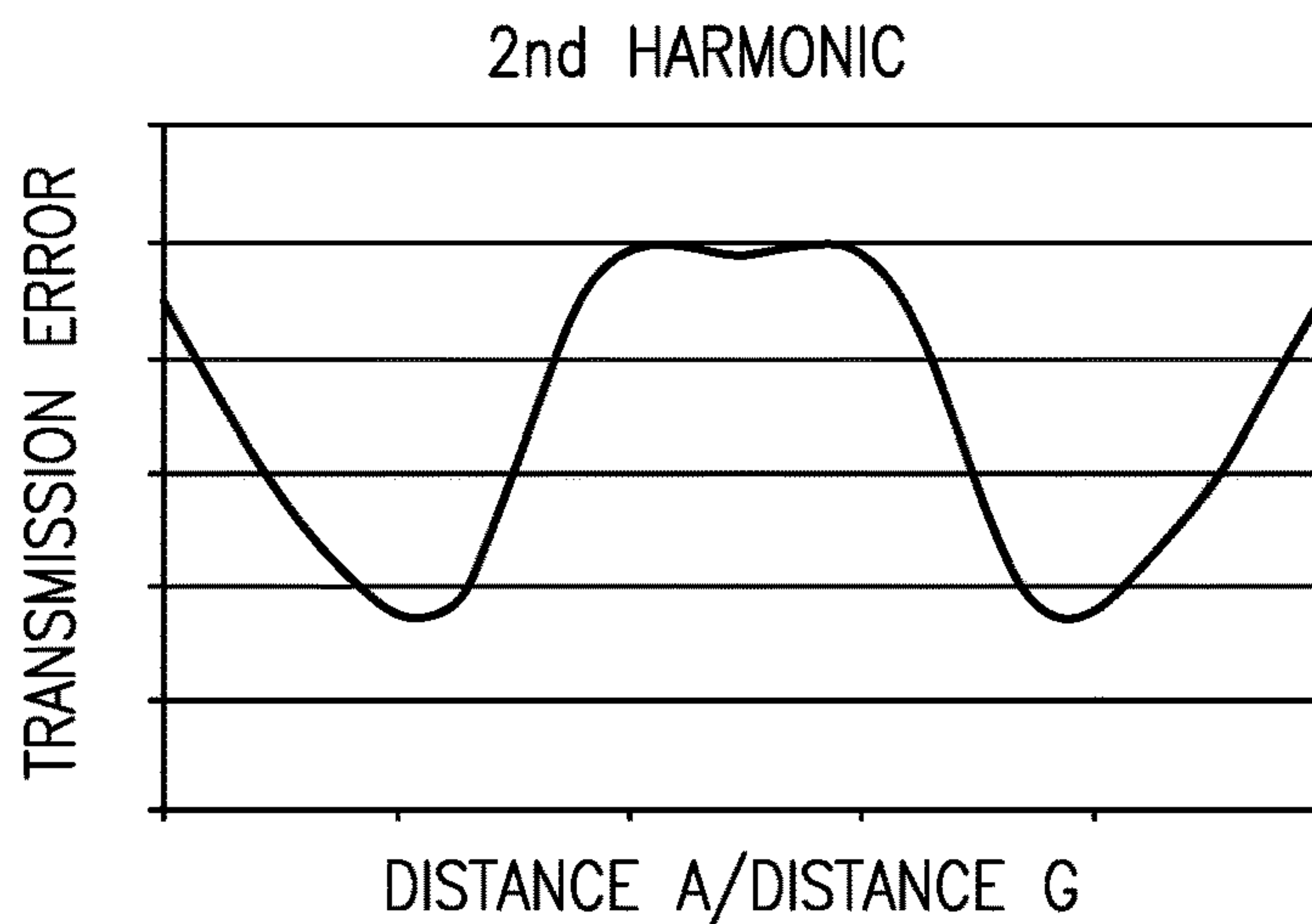
**FIG. 4**



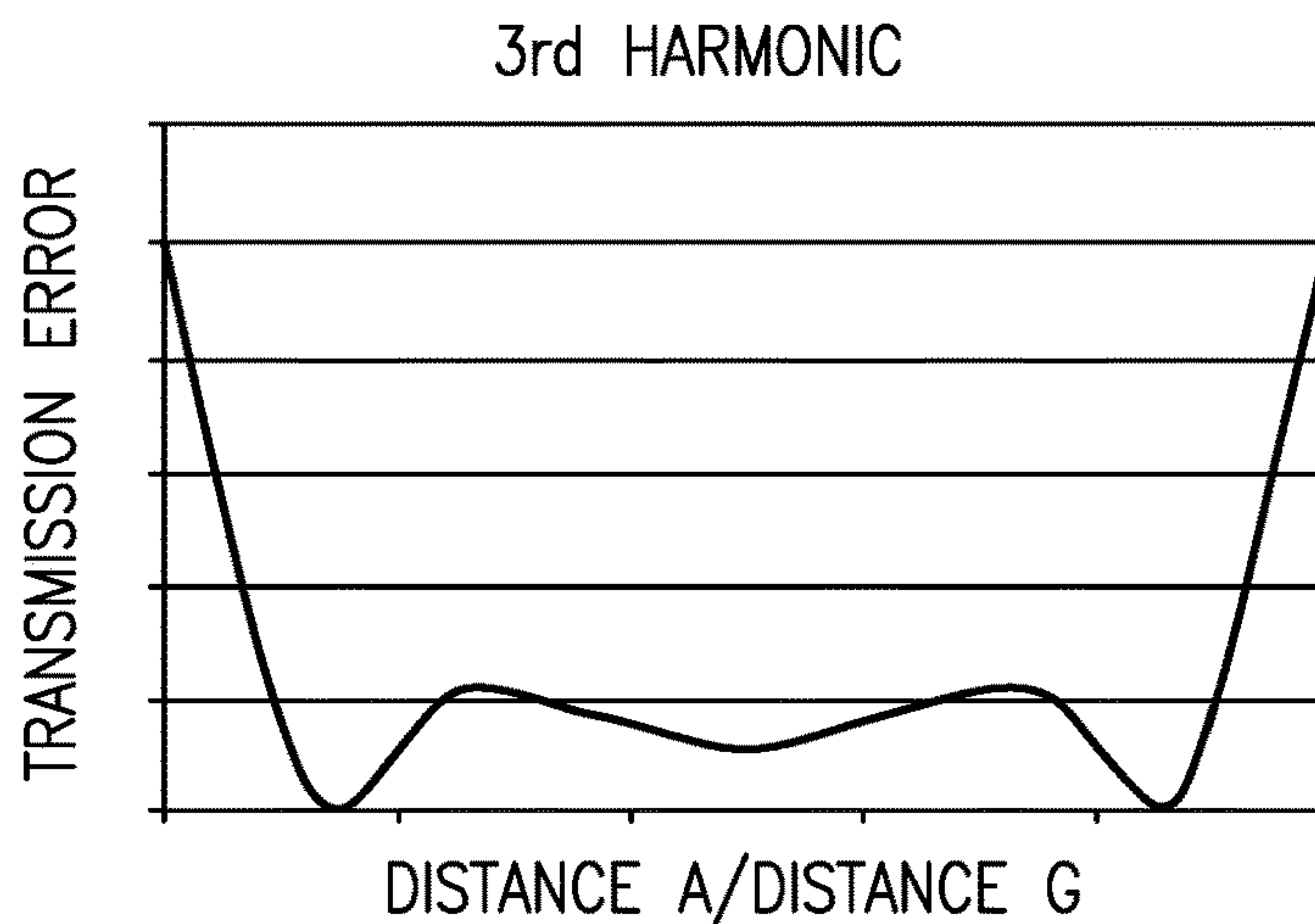
**FIG.5A**



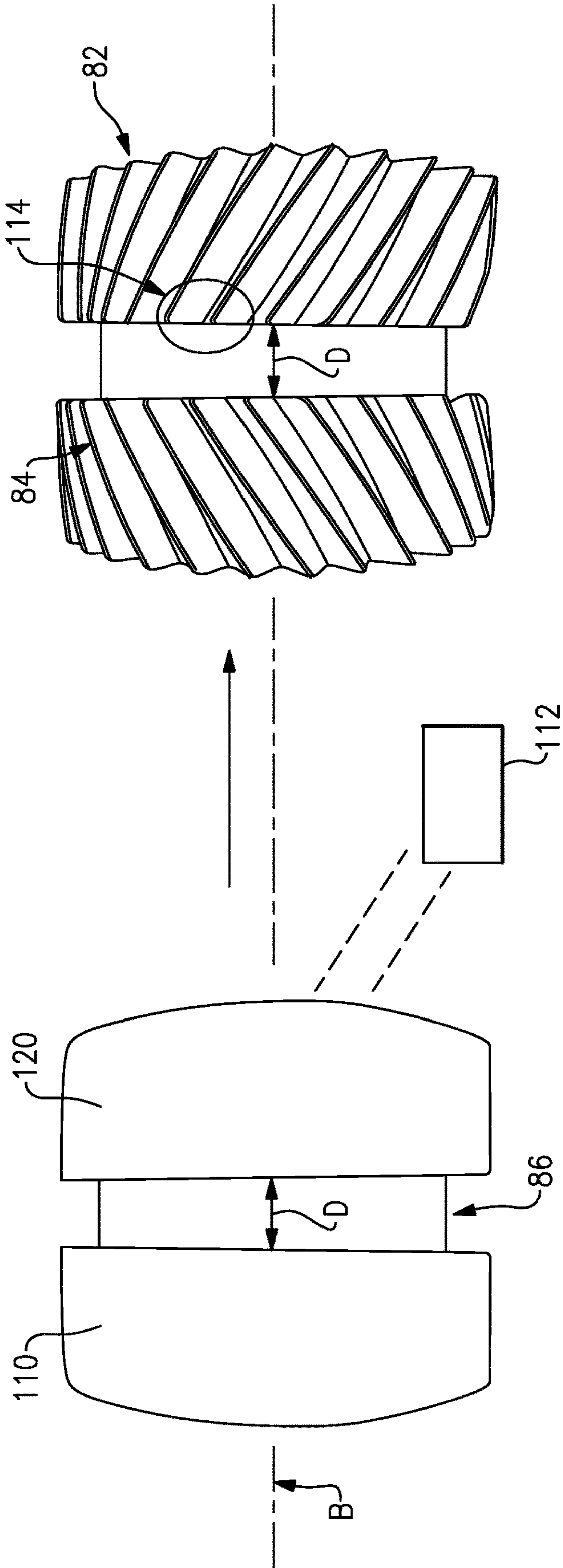
**FIG.5B**



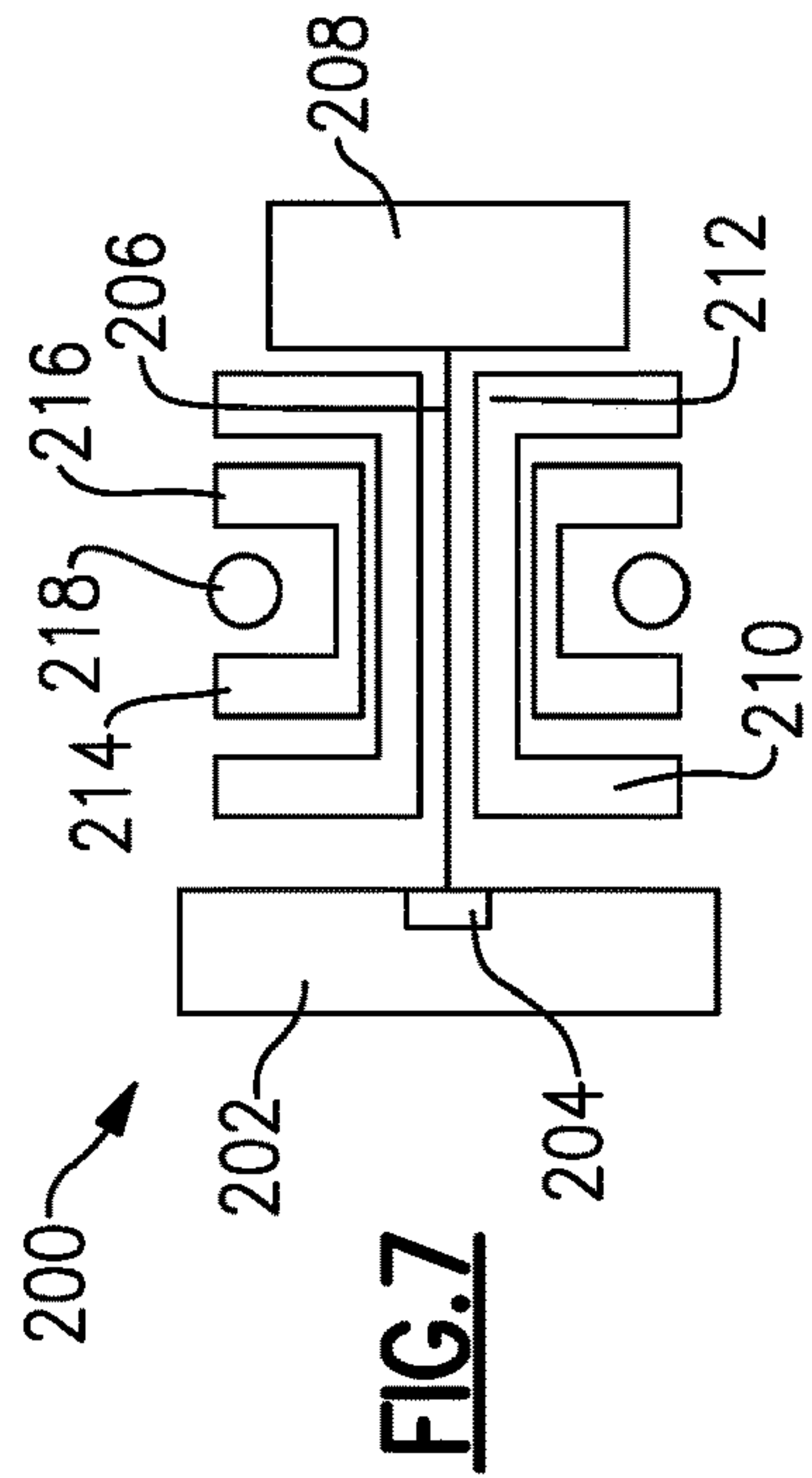
**FIG.5C**



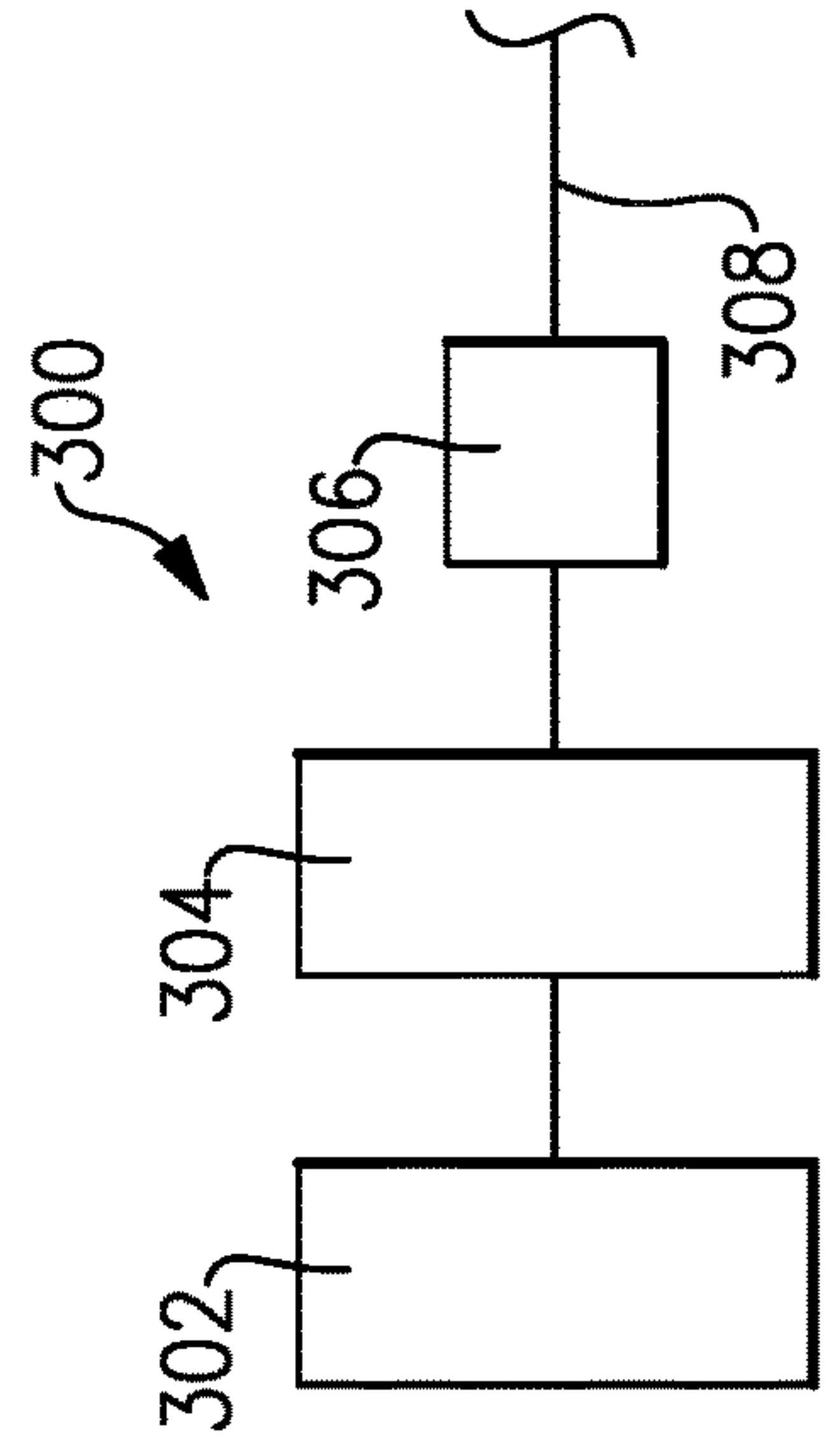




**FIG. 6**



**FIG. 7**



**FIG. 8**



**1****TURBINE ENGINE GEARBOX****CROSS REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of U.S. patent application Ser. No. 15/943,812, filed Apr. 3, 2018, which is a continuation of U.S. patent application Ser. No. 14/940,632, filed Nov. 13, 2015, which is a continuation of U.S. patent application Ser. No. 14/470,982, filed Aug. 28, 2014, which is a continuation of U.S. patent application Ser. No. 14/174,878, filed Feb. 7, 2014, which is a continuation-in-part of U.S. patent application Ser. No. 13/438,245, filed on Apr. 3, 2012, which claims priority to U.S. Provisional Application No. 61/592,964, filed on Jan. 31, 2012.

**BACKGROUND**

This disclosure relates generally to a turbine engine, and more specifically to a gearbox for a gas turbine engine.

A turbine engines includes a fan driven by a turbine. A gearbox is coupled between the fan to the turbine. The gearbox provides a speed decrease between the turbine and the fan.

**SUMMARY**

In a featured embodiment, a gas turbine engine has a fan, a compressor and a combustor, and a fan drive turbine rotor to drive the fan through a gear reduction. The gear reduction includes at least two double helical gears in meshed engagement, each of the at least two double helical gears disposed to rotate about respective axes, and each of the at least two double helical gears having a first plurality of gear teeth axially spaced from a second plurality of gear teeth by a spacer. Each of the first plurality of gear teeth has a first end facing the spacer and each of the second plurality of gear teeth has a first end facing the spacer. Each first end of the first plurality of gear teeth is circumferentially offset from each first end of the second plurality of gear teeth. A gear ratio of the gear reduction is greater than about 2.3:1.

In another embodiment according to the previous embodiment, the fan drive turbine drives a compressor rotor of the compressor, along with the fan through the gear reduction.

In another embodiment according to any of the previous embodiments, the gear reduction includes an epicyclic gear system.

In another embodiment according to any of the previous embodiments, the gear reduction is an epicyclic gear system that includes a sun gear, a ring gear, and a plurality of intermediate gears that engage the sun gear and ring gear.

In another embodiment according to any of the previous embodiments, the at least two helical gears are part of the plurality of intermediate gears.

In another embodiment according to any of the previous embodiments, the gear ratio of the gear reduction is greater than or equal to about 2.5:1.

In another embodiment according to any of the previous embodiments, there are two additional turbine rotors, with one of the two additional turbine rotors driving a low pressure compressor rotor, and a second of the additional turbine rotors driving a high pressure compressor rotor.

In another embodiment according to any of the previous embodiments, the gear reduction includes an epicyclic gear system.

In another embodiment according to any of the previous embodiments, the gear reduction is an epicyclic gear system

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that includes a sun gear, a ring gear, and a plurality of intermediate gears that engage the sun gear and ring gear.

In another embodiment according to any of the previous embodiments, the at least two helical gears are part of the plurality of intermediate gears.

In another featured embodiment, a method of designing a gas turbine engine includes providing a fan, a compressor and a combustor, and providing a fan drive turbine rotor to drive the fan through a gear reduction. The gear reduction includes at least two double helical gears in meshed engagement. Each of the at least two double helical gears are disposed to rotate about respective axes. Each of the at least two double helical gears have a first plurality of gear teeth axially spaced from a second plurality of gear teeth by a spacer. Each of the first plurality of gear teeth has a first end facing the spacer and each of the second plurality of gear teeth has a first end facing the spacer. Each first end of the first plurality of gear teeth is circumferentially offset from each first end of the second plurality of gear teeth. A gear ratio of the gear reduction is greater than about 2.3:1.

In another embodiment according to the previous embodiment, the fan drive turbine drives a compressor rotor, along with the fan through the gear reduction.

In another embodiment according to any of the previous embodiments, the gear reduction is an epicyclic gear system that includes a sun gear, a ring gear, and a plurality of intermediate gears that engage the sun gear and ring gear.

In another embodiment according to any of the previous embodiments, the at least two helical gears are part of the plurality of intermediate gears.

In another embodiment according to any of the previous embodiments, the gearbox includes an epicyclic gear system.

In another embodiment according to any of the previous embodiments, the gear reduction is an epicyclic gear system that includes a sun gear, a ring gear, and a plurality of intermediate gears that engage the sun gear and ring gear.

In another embodiment according to any of the previous embodiments, the at least two helical gears are part of the plurality of intermediate gears.

In another embodiment according to any of the previous embodiments, the gear ratio of the gear reduction is greater than or equal to about 2.5:1.

In another embodiment according to any of the previous embodiments, there are two additional turbine rotors, with one of the two additional turbine rotors driving a low pressure compressor rotor, and a second of the additional turbine rotors driving a high pressure compressor rotor.

These and other features can be best understood from the following specification and drawings, the following of which is a brief description.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a cross-sectional view of an example gas turbine engine.

FIG. 2 is a perspective view of example gearbox.

FIG. 3 is a perspective view of an example double helical gear.

FIG. 4 is a top schematic view of teeth of the example double helical gear of FIG. 3.

FIGS. 5A-5C are graphs illustrating example transmission error and gear teeth offsetting of the example double helical gear of FIG. 3.

FIG. 6 is a perspective view of the steps of forming the example double helical gear of FIG. 3.



FIG. 7 shows an alternative embodiment.  
FIG. 8 shows another alternative embodiment.

## DETAILED DESCRIPTION

FIG. 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 is disclosed herein as a two-spool turbofan that generally incorporates a fan section 22, a compressor section 24, a combustor section 26 and a turbine section 28. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section 22 drives air along a bypass flow path B in a bypass duct defined within a nacelle 15, while the compressor section 24 drives air along a core flow path C for compression and communication into the combustor section 26 then expansion through the turbine section 28. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.

The exemplary engine 20 generally includes a low speed spool 30 and a high speed spool 32 mounted for rotation about an engine central longitudinal axis A relative to an engine static structure 36 via several bearing systems 38. It should be understood that various bearing systems 38 at various locations may alternatively or additionally be provided, and the location of bearing systems 38 may be varied as appropriate to the application.

The low speed spool 30 generally includes an inner shaft 40 that interconnects a fan 42, a first (or low) pressure compressor 44 and a first (or low) pressure turbine 46. The inner shaft 40 is connected to the fan 42 through a speed change mechanism, which in exemplary gas turbine engine 20 is illustrated as a geared architecture 48 to drive the fan 42 at a lower speed than the low speed spool 30. The high speed spool 32 includes an outer shaft 50 that interconnects a second (or high) pressure compressor 52 and a second (or high) pressure turbine 54. A combustor 56 is arranged in exemplary gas turbine 20 between the high pressure compressor 52 and the high pressure turbine 54. A mid-turbine frame 57 of the engine static structure 36 is arranged generally between the high pressure turbine 54 and the low pressure turbine 46. The mid-turbine frame 57 further supports bearing systems 38 in the turbine section 28. The inner shaft 40 and the outer shaft 50 are concentric and rotate via bearing systems 38 about the engine central longitudinal axis A which is collinear with their longitudinal axes.

The core airflow is compressed by the low pressure compressor 44 then the high pressure compressor 52, mixed and burned with fuel in the combustor 56, then expanded over the high pressure turbine 54 and low pressure turbine 46. The mid-turbine frame 57 includes airfoils 59 which are in the core airflow path C. The turbines 46, 54 rotationally drive the respective low speed spool 30 and high speed spool 32 in response to the expansion. It will be appreciated that each of the positions of the fan section 22, compressor section 24, combustor section 26, turbine section 28, and fan drive gear system 48 may be varied. For example, gear system 48 may be located aft of combustor section 26 or even aft of turbine section 28, and fan section 22 may be positioned forward or aft of the location of gear system 48.

The engine 20 in one example is a high-bypass geared aircraft engine. In a further example, the engine 20 bypass ratio is greater than about six (6), with an example embodiment being greater than about ten (10), the geared architecture 48 is an epicyclic gear train, such as a star system, a

planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3 and the low pressure turbine 46 has a pressure ratio that is greater than about five. In one disclosed embodiment, the engine 20 bypass ratio is greater than about ten (10:1), the fan diameter is significantly larger than that of the low pressure compressor 44, and the low pressure turbine 46 has a pressure ratio that is greater than about five 5:1. Low pressure turbine 46 pressure ratio is pressure measured prior to inlet of low pressure turbine 46 as related to the pressure at the outlet of the low pressure turbine 46 prior to an exhaust nozzle. The geared architecture 48 may be an epicycle gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans.

A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section 22 of the engine 20 is designed for a particular flight condition—typically cruise at about 0.8 Mach and about 35,000 feet. The flight condition of 0.8 Mach and 35,000 ft, with the engine at its best fuel consumption—also known as “bucket cruise Thrust Specific Fuel Consumption (‘TSFC’)”—is the industry standard parameter of lbf of fuel being burned divided by lbf of thrust the engine produces at that minimum point. “Low fan pressure ratio” is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane (“FEGV”) system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. “Low corrected fan tip speed” is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of  $[(T_{\text{ram}} / 518.7) / (518.7 / R)]^{0.5}$ . The “Low corrected fan tip speed” as disclosed herein according to one non-limiting embodiment is less than about 1150 ft/second.

As can be appreciated, the low pressure turbine 46 is a fan drive turbine, as it drives the fan rotor 42. In the disclosed two-spool embodiment, the turbine 46 also drives a lower pressure compressor 44.

FIG. 2 shows an example of the gearbox 48 as the epicyclic gear system 68 driven by the low speed spool 30. The epicyclic gear system 68 includes a sun gear 70, star gears 72, a ring gear 74, and a carrier 77. The sun gear 70 engages the star gears 72 and each star gear 72 engages the ring gear 74. In this example, each of the sun gear 70, star gears 72, and ring gear 74 are double helical gears, as will be described in further detail below.

Rotary motion of sun gear 70 urges each star gear 72 arranged about the sun gear 70 to rotate about their own respective axis M. The star gears 72 mesh with both the rotating ring gear 74 and rotating sun gear 70. The star gears 72 rotate about their respective axis M to drive the ring gear 74 to rotate about engine axis A. The rotation of the ring gear 74 drives the fan 42 (FIG. 1) at a lower speed than the low speed spool 30. The ring gear 74 is a split assembly and includes a first section 73 and a second section 75 that are urged together by the star gears 72.

In one example, the sun gear 70, star gears 72, and ring gear 74 have a transverse contact ratio greater than two (2) such that at least two gear teeth of each gear 70, 72, 74 engage at least two gear teeth of another gear 70, 72, 74 during operation.

The gearbox 48 is subject to variations in torque transfer due to geometry and manufacturing tolerances. These variations cause vibrations in the gearbox 48, which are imparted



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on other associated turbine engine components. The resultant vibration affects durability of gearbox **48** components, and associated turbine engine components, thus affecting the life of the gearbox **48** and gas turbine engine **20** components.

FIGS. **3** and **4** shows an example of one of the star gears **72** as a double helical gear. It is to be understood that the described examples herein are also applicable to the sun gear **70**, and ring gear **74**, as well as other gears or gear systems of the gas turbine engine **20**.

The star gear **72** includes a first plurality of gear teeth **82** disposed on a first base **83** opposite a second plurality of gear teeth **84** disposed on a second base **85** along axis E. The first plurality of gear teeth **82** and the second plurality of gear teeth **84** are separated by a non-toothed ring **86** disposed about axis E such that a first end **90a** of the first plurality of gear teeth **82** and a first end **90b** of the second plurality of gear teeth **84** are spaced apart an axial distance D equal to the width of the ring **86**. The first plurality of gear teeth **82** and the second plurality of gear teeth **84** are rotatable around axis E.

In one example, the axial distance D of the width of non-toothed ring **86** is between 16% and 24% of the total axial length of the gear. In a further example, the first plurality of gear teeth **82** and the second plurality of gear teeth **84** each have an equal helix angle Z. In a further example, each of the first plurality of gear teeth **82** and the second plurality of gear teeth **84** have the same helix angle Z such that no axial thrust load is generated along axis E.

In another example, helix angle Z of the first plurality of gear teeth **82** is different than the helix angle Z of the second plurality of gear teeth **84**, to generate a pre-determined thrust load along axis E in the gas turbine engine **20**.

Each of the second plurality of gear teeth **84** includes the first end **90b** and a second end **92b**. Similarly, each of the first plurality of gear teeth includes the first end **90a** and a second end **92a**. In one example, the second plurality of gear teeth **84** is offset a circumferential offset distance A in relation to the next gear tooth **82** of the first plurality of gear teeth **82** when moving in circumferential direction of arrow **90**. The first end **90a** of each of the first plurality of gear teeth **82** is similarly spaced a circumferential offset distance B apart from the first end **90b** of the next corresponding gear tooth **84** of the second plurality of gear teeth **84** when moving in direction of arrow **90**. Circumferential offset distance G is a total of the circumferential offset distance A and the circumferential offset distance B between adjacent teeth of the second plurality of gear teeth **84** or first plurality of gear teeth **82**.

Each of the first plurality of gear teeth **82** and second plurality of gear teeth **84** are arranged at the helix angle Z between axis E and a circumferential surface **87** each of the first plurality of gear teeth **82** and the second plurality of gear teeth **84**. In this example, each of the first plurality of gear teeth **82** and the second plurality of gear teeth **84** are arranged at an equivalent helix angle Z relative to axis E.

In one example, the helix angle Z is between 30 and 35 degrees. In a further example, the helix angle Z is 33 degrees. The given helix angle Z or range urges the first section **73** and second section **75** of the ring gear **74** together.

The selected helix angle Z also influences the dynamics of the gearbox **48**. As the helix angle Z increases from 0, a greater number of gear teeth **82**, **84** engage teeth **82**, **84** of a mating sun gear **70** and ring gear **74** (See FIG. **2**). Selecting the first plurality of gear teeth **82** and second plurality of gear teeth **84** with the disclosed helix angle Z provides additional contact, and higher torque transfer, while maintaining the size of star gear **72**.

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Circumferential offset distance A and circumferential offset distance B are determined and used to offset each of the first plurality of gear teeth **82** from the next corresponding tooth **84** of the second plurality of gear teeth **84** between 0% and 100% of the circumferential offset distance G between each of the respective first plurality of gear teeth **82** or second plurality of gear teeth **84**. In another example, the first plurality of gear teeth **82** are between about 25% to 75% offset from the second plurality of gear teeth **84** such that the ratio of circumferential offset distance A to circumferential offset distance G is between about 0.25 and 0.75. In a further example, the first plurality of gear teeth **82** are 50% offset from the second plurality of gear teeth **84**, such that circumferential offset distance A and circumferential offset distance B are equal.

In another example, the circumferential offset distance A is selected in response to a gear characteristic of the star gear **72**. The gear characteristic is at least one of harmonic level, transmission error, and vibration level through the star gear **72**.

FIGS. **5A-5C** show the circumferential offset distance A is pre-determined to provide a percent offset (axis X) in response to a frequency of the star gear **72** during meshing of star gears **72** in the gearbox **48**. The percent offset results in a change in transmission error to effect the chosen frequency. Performance of the star gear **72** is controlled in response to the frequency based on the selected percent offset to reduce or minimize the amount of transmission error and vibration.

The frequency represents a harmonic level. In this example, a first harmonic has a frequency equal to the number of teeth on the sun gear times the revolutions per second of the sun gear relative to the carrier **77**, a second harmonic has a frequency of 2 times the first harmonic, and a third harmonic has a frequency of 3 times the first harmonic. For each of the first harmonic, second harmonic, and third harmonic, transmission error is controlled by selecting a pre-determined percent offset between the first plurality of gear teeth **82** and second plurality of gear teeth **84**, as equates to circumferential offset distance A and circumferential offset distance B. Transmission error is defined herein as the deviation between the circumferential position that the star gear **72** should have and the actual position during meshing.

In one example, as shown in FIG. **5A**, the first plurality of gear teeth **82** are between about 25% to 75% offset from the second plurality of gear teeth **84** such that a ratio of circumferential offset distance A to circumferential offset distance G is between about 0.25 and 0.75 to reduce transmission error in the first harmonic.

In a further example, as shown in FIG. **5B**, the first plurality of gear teeth **82** are between about 15% to 25% or 75% to 85% offset from the second plurality of gear teeth **84** such that a ratio of circumferential offset distance A to circumferential offset distance G is between about 0.15 and 0.25 or between about 0.75 and 0.85 to reduce transmission error in the second harmonic.

In a further example, as shown in FIG. **5C**, the first plurality of gear teeth **82** are between about 15% to 85% offset from the second plurality of gear teeth **84** such that a ratio of circumferential offset distance A to circumferential offset distance G is between about 0.15 and 0.85 to reduce transmission error in the third harmonic.

In a further embodiment, the first plurality of gear teeth **82** are offset about 50% from the second plurality of gear teeth **84** such that a ratio of circumferential offset distance A to



circumferential offset distance G is about 0.5 to reduce transmission error in the first harmonic and the third harmonic.

Offsetting the first plurality of gear teeth **82** and the second plurality of gear teeth **84** the circumferential offset distance A or circumferential offset distance B reduces the overall transmission error of the gearbox **48**. Circumferential offset distance A and circumferential offset distance B are determined depending on the harmonic level(s) of the star gears **72** during meshing. Performance of the gearbox **48**, which is controlled by reduction in transmission error, reduces vibration in the gearbox **48** and gas turbine engine **20** during operation. Thus, torque transfer is smoother, with less overall effect on engine component life and efficiency due to vibration.

Referring to FIG. 6, an example method of forming the star gear **72** is shown. A first cylinder **110** and second cylinder **120** are arranged on either axial side of ring **86** along axis E. A tool **112** (shown schematically) is provided and machines grooves in the first cylinder **110** and the second cylinder **120** to form the first plurality of gear teeth **82** and second plurality of gear teeth **84**. The first plurality of gear teeth **82** and second plurality of gear teeth **84** are arranged at an helix angle Z and offset an circumferential offset distance A and circumferential offset distance B, as described above. After one of the first plurality of gear teeth **82** and second plurality of gear teeth **84** are formed, the tool **112** is used to form the remaining plurality of gear teeth **82**, **84** without affecting the dimensions of the already formed first plurality of gear teeth **82** or second plurality of gear teeth **84**. As shown in FIG. 6, the star gear **72** is a one-piece gear formed from the first and second cylinders **110**, **120**, with the portions of the star gear **72** defining the gear teeth **82**, **84** fixed to each other by the ring **86**. The space between first cylinder **110** and second cylinder **120** provided by ring **86** allows the tool **112** to form the plurality of gear teeth **82**, **84** without affecting the already formed plurality of gear teeth **82**, **84**. By offsetting the first plurality of gear teeth **82** and second plurality of gear teeth **84**, the tool **112** is able to move into the space **114** between the already formed plurality of gear teeth **82**, **84**, thus reducing the width D of ring **86** needed to form the unformed plurality of gear teeth **82**, **84**. The reduction of width D decreases the weight of the star gear **72**.

Although the example first cylinder **110** and second cylinder **120** are shown, it is within the contemplation of this disclosure to use other geometrical sections to form the star gear **72** based on gas turbine engine **20** specifications. In one example, the tool **112** is a grinding wheel.

FIG. 7 shows an embodiment **200**, wherein there is a fan drive turbine **208** driving a shaft **206** to in turn drive a fan rotor **202**. A gear reduction **204** may be positioned between the fan drive turbine **208** and the fan rotor **202**. This gear reduction **204** may be structured, mounted and operate like the gear reduction disclosed above. A compressor rotor **210** is driven by an intermediate pressure turbine **212**, and a second stage compressor rotor **214** is driven by a turbine rotor **216**. A combustion section **218** is positioned intermediate the compressor rotor **214** and the turbine rotor **216**.

FIG. 8 shows yet another embodiment **300** wherein a fan rotor **302** and a first stage compressor **304** rotate at a common speed. The gear reduction **306** (which may be structured, mounted and operated as disclosed above) is intermediate the compressor rotor **304** and a shaft **308** which is driven by a low pressure turbine section.

Although a preferred embodiment has been disclosed, a worker of ordinary skill in this art would recognize that

certain modifications would come within the scope of this disclosure. For that reason, the following claims should be studied to determine the true scope and content of this disclosure.

What is claimed is:

1. A turbofan engine comprising:

a fan section including a fan and an outer housing surrounding the fan to define a bypass duct;

a compressor section including a low pressure compressor and a high pressure compressor;

a gear reduction; and

a turbine section including a fan drive turbine and a high pressure turbine, wherein the fan drive turbine drives the fan through the gear reduction;

wherein the gear reduction is an epicyclic gear system that includes a carrier and a plurality of gears, and the plurality of gears including a sun gear, a ring gear, and a plurality of intermediate gears that engage the sun gear and the ring gear;

wherein at least two of the plurality of gears are double helical gears in meshed engagement, each of the double helical gears disposed to rotate about respective axes, each of the double helical gears having a first plurality of gear teeth separated from a second plurality of gear teeth such that a first end of the first plurality of gear teeth and a first end of the second plurality of gear teeth are spaced apart by an axial distance;

wherein each of the first plurality of gear teeth is offset a first circumferential offset distance in relation to a next gear tooth of the second plurality of gear teeth when moving in a circumferential direction relative to the respective axes, each of the second plurality of gear teeth is offset a second circumferential offset distance in relation to a next gear tooth of the first plurality of gear teeth when moving in the circumferential direction, a third circumferential offset distance being a total of the first circumferential offset distance and the second circumferential offset distance, and a ratio of the first circumferential offset distance and the third circumferential offset distance is between 0.25 and 0.75; and

wherein each gear tooth of the first plurality of gear teeth and the second plurality of gear teeth is disposed at a respective helix angle relative to the respective axes, and the helix angle of the first plurality of gear teeth is different from the helix angle of the second plurality of gear teeth.

2. The turbofan engine as set forth in claim 1, further comprising:

a bypass ratio of greater than 10:1; and

wherein the fan has a low fan pressure ratio of less than 1.45 across a fan blade alone.

3. The turbofan engine as set forth in claim 2, wherein: each of the plurality of intermediate gears is one of the double helical gears; and

the sun gear, the intermediate gears and the ring gear have a transverse contact ratio of greater than 2 such that at least two gear teeth of each of the sun gear, the intermediate gears and the ring gear engage at least two gear teeth of another one of the sun gear, the intermediate gears and the ring gears in operation.

4. The turbofan engine as set forth in claim 3, wherein the first plurality of gear teeth and the second plurality of gear teeth are separated by a spacer disposed about the respective axis.

5. The turbofan engine as set forth in claim 4, wherein the spacer is dimensioned such that the axial distance is equal to



between 16% and 24% of a total axial length of a respective one of the double helical gears relative to the respective axis.

6. The turbofan engine as set forth in claim 4, wherein a gear reduction ratio of the gear reduction is greater than 2.3:1.

7. The turbofan engine as set forth in claim 6, wherein the gear reduction is a star system, and rotation of the ring gear drives the fan at a lower speed than an input to the gear reduction.

8. The turbofan engine as set forth in claim 7, wherein the ring gear is a split assembly that includes a first section and a second section that are urged together by the plurality of intermediate gears in response to rotation of the plurality of intermediate gears.

9. The turbofan engine as set forth in claim 6, wherein the gear reduction is a planetary system.

10. The turbofan engine as set forth in claim 6, wherein the high pressure turbine includes two stages, the fan drive turbine includes a greater number of stages than the high pressure turbine, and the low pressure compressor includes three stages.

11. The turbofan engine as set forth in claim 10, wherein the fan drive turbine includes an inlet, an outlet and a pressure ratio of greater than 5, the pressure ratio being pressure measured prior to the inlet as related to pressure at the outlet prior to an exhaust nozzle, and further comprising a low corrected fan tip speed of less than 1150 feet/second.

12. The turbofan engine as set forth in claim 11, wherein the helix angle is between 30 degrees and 35 degrees.

13. The turbofan engine as set forth in claim 12, wherein the axial distance is equal to a width of the spacer, and the axial distance is equal to between 16% and 24% of a total axial length of a respective one of the double helical gears relative to the respective axis.

14. The turbofan engine as recited in claim 13, wherein each of the sun gear, the plurality of intermediate gears, and the ring gear is a respective one of the double helical gears.

15. The turbofan engine as set forth in claim 13, wherein the ring gear is a split assembly that includes a first section and a second section that are urged together by the plurality of intermediate gears in response to rotation of the plurality of intermediate gears.

16. The turbofan engine as set forth in claim 15, wherein the ratio of the first circumferential offset distance and the third circumferential offset distance is 0.50.

17. The turbofan engine as set forth in claim 16, wherein the gear reduction ratio is greater than 2.5:1, and the fan drive turbine drives the low pressure compressor.

18. A turbofan engine comprising:

a fan section including a fan and an outer housing surrounding the fan to define a bypass duct;

a compressor section including a low pressure compressor and a high pressure compressor;

a gear reduction; and

a turbine section including a fan drive turbine and a high pressure turbine, wherein the fan drive turbine drives the fan through the gear reduction;

wherein the gear reduction is an epicyclic gear system that includes a carrier and a plurality of gears, and the plurality of gears including a sun gear, a ring gear, and a plurality of intermediate gears that engage the sun gear and the ring gear;

wherein at least two of the plurality of gears are double helical gears in meshed engagement, each of the double helical gears disposed to rotate about respective axes, each of the double helical gears is a one-piece gear having a first plurality of gear teeth separated from a

second plurality of gear teeth such that a first end of the first plurality of gear teeth and a first end of the second plurality of gear teeth are spaced apart by an axial distance; and

wherein each of the first plurality of gear teeth is offset a first circumferential offset distance in relation to a next gear tooth of the second plurality of gear teeth when moving in a circumferential direction relative to the respective axes, each of the second plurality of gear teeth is offset a second circumferential offset distance in relation to a next gear tooth of the first plurality of gear teeth when moving in the circumferential direction, a third circumferential offset distance being a total of the first circumferential offset distance and the second circumferential offset distance, and a ratio of the first circumferential offset distance and the third circumferential offset distance is between 0.25 and 0.75; wherein each of the plurality of intermediate gears is a respective one of the double helical gears; and wherein the first plurality of gear teeth and the second plurality of gear teeth are disposed at a helix angle relative to the respective axes, and the helix angle is between 30 degrees and 35 degrees.

19. The turbofan engine as set forth in claim 18, wherein each gear tooth of the first plurality of gear teeth and the second plurality of gear teeth is disposed at a respective helix angle relative to the respective axes, and the respective helix angle of the first plurality of gear teeth is different from the respective helix angle of the second plurality of gear teeth.

20. The turbofan engine as set forth in claim 18, wherein each gear tooth of the first plurality of gear teeth and the second plurality of gear teeth is disposed at a respective helix angle relative to the respective axes, and each of the first plurality of gear teeth and the second plurality of gear teeth have the same helix angle.

21. The turbofan engine as set forth in claim 20, further comprising:

a bypass ratio of greater than 10:1; and

a low corrected fan tip speed of less than 1150 feet/second; and

wherein the fan has a low fan pressure ratio of less than 1.45 across a fan blade alone.

22. The turbofan engine as set forth in claim 21, wherein the high pressure turbine includes two stages, the fan drive turbine includes a greater number of stages than the high pressure turbine, and the low pressure compressor includes three stages.

23. The turbofan engine as set forth in claim 22, wherein: a gear reduction ratio of the gear reduction is greater than 2.3:1; and

the fan drive turbine includes an inlet, an outlet and a pressure ratio of greater than 5, the pressure ratio being pressure measured prior to the inlet as related to pressure at the outlet prior to an exhaust nozzle.

24. The turbofan engine as set forth in claim 23, wherein the ring gear is a split assembly that includes a first section and a second section that are urged together by the plurality of intermediate gears in response to rotation of the plurality of intermediate gears.

25. A turbofan engine comprising:

a fan section including a fan and an outer housing surrounding the fan to define a bypass duct;

a compressor section including a low pressure compressor and a high pressure compressor;

a gear reduction; and



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a turbine section including a fan drive turbine and a high pressure turbine, wherein the fan drive turbine drives the fan through the gear reduction;

wherein the gear reduction is an epicyclic gear system that includes a carrier and a plurality of gears, and the plurality of gears including a sun gear, a ring gear, and a plurality of intermediate gears that engage the sun gear and the ring gear;

wherein at least two of the plurality of gears are double helical gears in meshed engagement, each of the double helical gears disposed to rotate about respective axes, each of the double helical gears is a one-piece gear having a first plurality of gear teeth separated from a second plurality of gear teeth such that a first end of the first plurality of gear teeth and a first end of the second plurality of gear teeth are spaced apart by an axial distance;

wherein each of the first plurality of gear teeth is offset a first circumferential offset distance in relation to a next gear tooth of the second plurality of gear teeth when moving in a circumferential direction relative to the respective axes, each of the second plurality of gear teeth is offset a second circumferential offset distance in relation to a next gear tooth of the first plurality of

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gear teeth when moving in the circumferential direction, a third circumferential offset distance being a total of the first circumferential offset distance and the second circumferential offset distance, and a ratio of the first circumferential offset distance and the third circumferential offset distance is between 0.15 and 0.85; wherein each of the plurality of intermediate gears is a respective one of the double helical gears; and wherein the ratio of the first circumferential offset distance and the third circumferential offset distance is between 0.15 and 0.25, or is between 0.75 and 0.85.

**26.** The turbofan engine as set forth in claim **25**, wherein each gear tooth of the first plurality of gear teeth and the second plurality of gear teeth is disposed at a respective helix angle relative to the respective axes, and the helix angle of the first plurality of gear teeth is different from the helix angle of the second plurality of gear teeth.

**27.** The turbofan engine as set forth in claim **25**, wherein each gear tooth of the first plurality of gear teeth and the second plurality of gear teeth is disposed at a respective helix angle relative to the respective axes, and each of the first plurality of gear teeth and the second plurality of gear teeth have the same helix angle.

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